

XLIV. *On the Existence of a Sexual Reproduction in the Infusoria.* By M. BALBIANI\*.

THE discovery of the propagation of the Infusoria by the production of embryos or internal germs, which has already been ascertained to prevail in a certain number of species belonging to different groups, has opened a new field of research in the history of the development of these animalcules. It has shown, in fact, that besides the two truly agamic modes of reproduction, by spontaneous division and gemmiparity, previously admitted in this class, there exists a third mode, capable of a very different interpretation, and which has at least this point in common with the reproduction by embryos of the superior sexual species, that, as in the latter, the young are formed in the interior, if not in a special cavity of the parent which gives them birth. But no one has yet shown that the formation of the embryos in the Infusoria was accompanied by any of the circumstances which indubitably characterize a generation accomplished by the agency of distinct sexual apparatus. Stein was one of the first to call attention to the part played by the nucleus in this production; but he thought that the germs were developed on the surface of this body by a phænomenon of gemmation, which would assimilate them rather to bulbilli or caducous buds, than to embryos originating from fertile ova.

My own observations have led me to regard the origin of these bodies in a different light; I hope that I have been fortunate enough to demonstrate that the phænomena which accompany their formation enter perfectly into the series of those which, in the higher animals, are essentially characteristic of sexual generation. As I cannot, in this note, dwell at any length upon the facts which I have been enabled to observe, and which already relate to six or seven species representing different groups, I shall content myself with giving a rapid sketch of the phænomena relating to the embryonic reproduction of that species in which I have been able to trace it most completely,—the green *Paramecium* (*Paramecium bursaria*, Focke; *Loxodes bursaria*, Ehrenb.).

In this species, as in nearly all Infusoria, there exists a nucleus, which is accompanied here by a small lenticular body, usually lodged in an excavation of the nucleus, near one of its extremities, and generally described under the improper name of nucleolus.

For several generations the *Paramecia* multiply by spontaneous scission, each of the two new individuals obtaining half the primitive nucleus. Such is the very simple phænomenon of

\* Translated from the 'Comptes Rendus,' 29th March, 1858, p. 628.

this mode of reproduction; but under the influence of conditions of which we are still ignorant, the species propagates itself in a very different manner, and in the midst of phenomena far more complex than those which preside over the multiplication by fission. In this new mode we shall see the actual anatomical signification of the nucleus and nucleolus, the function of which, if we except the division of the former of these two organs in the act of spontaneous division, has hitherto been perfectly passive. It is, in fact, at their expense that the male and female reproductive elements which characterize this mode of propagation are formed.

When the period arrives at which the *Paramecia* are to propagate with concurrence of the sexes, they are seen assembling upon certain parts of the vessel, either towards the bottom, or on the walls. The copulation is always preceded by certain preliminaries which are very curious to observe, but upon which we cannot dwell here. Soon they are found coupled in pairs, adherent laterally and as it were locked together, with the similar extremities turned in the same direction, and the two mouths closely applied to each other. In this state the two conjugated individuals continue moving with agility in the liquid, and turning constantly round their axis. There is nothing, before the copulation, to announce the considerable changes which are about to take place in the nucleus, and the nucleolus which accompanies it. It is during the copulation itself, of which the duration is prolonged for five or six days or more, that their transformation into sexual reproductive apparatus takes place.

The nucleolus has undergone a considerable increase in size, and has become converted into a sort of capsule of an oval form, of which the surface presents longitudinal and parallel lines or streaks. Nearly always, it soon divides in the direction of its greater axis, into two, or more frequently into four parts, which continue increasing independently of each other, and in a very irregular manner, and form so many secondary sacs or capsules. At a period which is still near that of division, these latter appear to be composed of an extremely fine membrane, enveloping a bundle of small, curved bacilla, extending from one extremity of the sac to the other, inflated towards the middle, narrowed towards the extremities. It is these which, when seen through the enveloping membrane, give the capsule the striated appearance which is characteristic of it, and which even exists in the nucleolus at almost all the other periods of the life of the Infusorium. It also contains a perfectly colourless and homogeneous fluid.

At the same time the nucleus has also changed its form and aspect; it has become rounded and widened; its substance has become softer and lost its refractive power, and towards its mar-

gins it presents notches, which, penetrating more and more deeply into its mass, isolate one or more fragments, in which a sufficient magnifying power enables us to see a certain number of small transparent spheres with an obscure central point. In other cases the nucleus, whilst still almost entire, presents this aspect, and then appears as if stuffed with these little rounded bodies, the analogy of which to ovules cannot be doubted in the least. The evolution of the nucleus and nucleolus being identical and progressing at the same rate in the two coupled individuals, it follows, if from this moment we regard the former as an ovary, and the second as a testicle or seminal capsule, not only that each of them possesses the attributes of both sexes, but that they fecundate each other, and serve at the same time as male and female. As regards this fecundation itself, everything seems to prove that it takes place by means of an exchange made by the two coupled individuals of one or more of their seminal capsules, which pass, through the apertures of the mouths closely applied against each other, from the body of one *Paramecium* into that of the other; for, very often, although we may not be able to perceive this passage itself, we may at least detect the moment when one of the capsules already engaged in one of the mouths, is on the point of clearing this aperture. Does the exchange which causes fecundation take place with all the capsules in a single copulation, or in so many successive copulations with different individuals? This is a question the solution of which is not easy, and which, to keep within the field of our observations, we shall not attempt to solve at present.

However this may be, each capsule, after its transmission, still continues to increase in size in the body of the individual which has received it, for we have never found any which had attained the limit of their development in individuals which were still coupled. They then frequently attain a volume greater than that of the nucleus itself, but there is never more than one that arrives at maturity at the same time. When, having arrived at this state, it is examined after being pressed out of the body of the animalcule, to free it from the granulations which mask it more or less while there, it appears under the form of a large ovoid body, the surface of which presents a multitude of parallel striæ directed longitudinally, and due to the arrangement in series of the corpuscles contained in the interior. Compression carried so far as to cause its rupture, shows it distinctly to be formed by a membrane of extreme tenuity, and contents, enclosing an innumerable quantity of small fusiform corpuscles, of which the extremities are completely lost to sight in consequence of their extreme fineness. As soon as they are free, these little bodies show themselves to be animated by a vacillatory and

translatory movement, which soon causes their dispersion in the circumambient fluid. These are the spermatozoids of *P. bursaria*. Iodine, alcohol, and acetic acid instantly stop their movements; they are insoluble in the last-mentioned reagent when concentrated, although this dissolves all the other elements of the body, with the exception of the green granules.

It is usually from the fifth to the sixth day following the copulation, that the first germs are seen to make their appearance in the form of small rounded bodies, formed of a membrane which is rendered very evident by acetic acid, and greyish, pale, homogeneous, or almost imperceptibly granular contents, in which neither nucleus nor contractile vesicle is yet to be distinguished. These organs do not appear until afterwards. The observations of Stein and F. Cohn have shown how these embryos quit the body of the mother in the form of *Acinetæ* furnished with knobbed tentacles,—true suckers by means of which they remain for some time still adherent to the mother, deriving their nourishment from her substance; but their investigations did not reveal to them the ultimate fate of these young animalcules. I have been able to follow them for a considerable time after they detached themselves from the body of the mother, and have convinced myself that, after losing their suckers, becoming surrounded with vibratile cilia, and obtaining a mouth which first shows itself in the form of a longitudinal furrow, they definitely acquired the form of the mother, becoming penetrated in the same way by the green granulations characteristic of this *Paramecium*, without undergoing any more important metamorphoses.

#### BIBLIOGRAPHICAL NOTICE.

*A Cyclopaedia of the Natural Sciences.* By WILLIAM BAIRD, M.D., F.L.S. London and Glasgow. Griffin, 8vo, 1858.

THAT the preparation of even a popular dictionary of the Natural Sciences, including the wide range of Zoology, Botany and Mineralogy, is a task from which any one man might be well excused for recoiling, will be readily admitted on all hands;—such a work is a gigantic undertaking, in which complete success can hardly be looked for. In the present case, the difficulty is not lessened by the fact that the information to be communicated on this extensive series of subjects had to be selected and compressed, so as to occupy only a single volume; and although this is a stout octavo of more than six hundred pages, those who are at all familiar with natural history will scarcely need to be told that the work of selection and compression must have been an arduous piece of business.

Making due allowance for the acknowledged difficulties besetting